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Issued May 8, 1911.

PORTO RICO AGRICULTURAL EXPERIMENT STATION

D. W. MAY, Special Agent in Charge.

Mayaguez, January, 1911.

Bulletin No. 10.

INSECTS INJURIOUS TO CITRUS FRUITS AND METHODS FOR COMBATING THEM.

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BY

W. V. TOWER,

Entomologist, Porto Rico Agricultural Experiment Station.

UNDER THE SUPERVISION OF

OFFICE OF EXPERIMENT STATIONS,

U. S. DEPARTMENT OF AGRICULTURE.

WASHINGTON:
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PORTO RICO AGRICULTURAL EXPERIMENT STATION.

[Under the supervision of A. C. True, Director of the Office of Experiment Stations, United States Department of Agriculture.]

Walter H. Evans,

Chief of Division of Insular Stations, Office of Experiment Stations.

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LETTER OF TRANSMITTAL.

PORTO RICO AGRICULTURAL EXPERIMENT STATION,
Mayaguez, P. R., January 27, 1911.

SIR: I have the honor to transmit herewith a manuscript on the subject of Insects Injurious to Citrus Fruits and Methods for Combating Them.

As the growing of citrus fruits is rapidly forging ahead and destined to be one of our leading industries, and as any information looking to its betterment by the employment of the most intelligent efforts in its promotion will be of value, the issuance of this bulletin is timely.

I respectfully recommend that this manuscript be issued as Bulletin No. 10 of this station and that it be published in both English and Spanish.

Respectfully,

D. W. MAY,
Special Agent in Charge.

Dr. A. C. TRUE,
Director Office of Experiment Stations,
U. S. Department of Agriculture, Washington, D. C.

Recommended for publication.
A. C. TRUE, *Director.*

Publication authorized.
JAMES WILSON,
Secretary of Agriculture.

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INSECTS INJURIOUS TO CITRUS FRUITS AND METHODS FOR COMBATING THEM.

INTRODUCTION.

The object of this bulletin is to describe the life history of some of the various insects injurious to citrus trees, and also to give the various insecticides which are being used and their effect on both trees and insects.

For years the planters of Florida have been spraying their trees with various emulsions to keep their fruit clean and trees healthy. The time has arrived for planters in Porto Rico to pay more attention to the appearance of their fruit if they desire to realize top-market prices. In order to grow clean fruit more spraying at the proper time is necessary. The experiment stations of the United States have shown that beneficial results may be obtained by spraying. Orchards that produced practically nothing but worthless fruit have been sprayed, with the result that 90 to 95 per cent of their fruit is perfect.

Previous to 1909 very little cultivated fruit had been shipped from this island, as most of the groves were young and the fruit poor in quality, little attention having been paid to its appearance. Now that the groves are maturing, more attention will have to be given to the appearance of the fruit in order to obtain a higher market standard. This can be done by carefully watching for the appearance of insects. Spraying should be done as soon as the insects appear, so that they will not multiply and ruin the crop. Planters should realize that systematic spraying is important, and that the work must be done thoroughly. Thorough work not only implies the use of specific kinds of insecticides, but also special care in their preparation.

There are a number of different kinds of insects which have become troublesome to citrus trees. Their successful combating depends largely on an intimate knowledge of their habits, life history, and physical characteristics. Without such knowledge it is impossible to anticipate an attack by them or to know the most effective means for their immediate elimination without injury to the trees, and frequently to the fruit itself. Parasitic factors are often more desirable in eliminating a pest than resort to treatment with insecticides, provided the parasite itself does not become a pest.

RELATION OF INSECTICIDES TO INSECTS.

Various kinds of insecticides are used for the different classes of insects because of structural differences in their mouth parts. There are two types of mouth parts—in one type they are constructed for chewing, while in the other they are drawn out into a tube which is inserted into the plant tissue to remove the juices by sucking. Insects of the former are more easily killed by stomach poisons and of the latter by contact poisons, while some of both may be kept away from plants and trees by means of repelling agents.

Stomach poisons are generally used on insects with chewing mouth parts, as, for example, the mole cricket and May beetle, although there are exceptions to the rule. Paris green and arsenate of lead are generally considered as the most efficient remedies of this class. They are usually sprayed upon the leaves that they may be swallowed with the food.

Contact poisons are generally used on insects with sucking mouth parts, of which the scale insects, plant lice, and the white fly are examples. Stomach poisons are of no avail against such, because they thrust their beaks into the tissues of the plant and thus avoid the poison on the surface. Contact poisons, on the other hand, fill up their breathing pores and smother them or cause death through irritation. Various emulsions made with carbolic acid, kerosene, crude oil, boiled lime sulphur, and miscible oils kill insects by contact.

Repelling agents can be used to advantage on some insects. In fact, some of the aforementioned agents, as carbolic acid and kerosene, serve this purpose, but when used for repelling purposes their preparation is more simple than when used as emulsions. Ants are sometimes successfully kept away from plants and trees by means of repellents, although their destruction is more certain with contact poisons applied in their nests.

ORANGE-LEAF WEEVIL.

(*Diaprepes spengleri.*)

The orange-leaf weevil appears during May, June, and July, and again in November, there being two broods a year; but a few of these insects can be found among the orange trees during the other months of the year.

The larva of this insect is a white grub, which feeds on the roots of the orange. In a few cases it was found damaging the trees to such an extent that the leaves turned yellow and dropped off. This insect, however, is not so destructive as the May beetle or its larva, the "caculo." The adult has other hosts, as the guava, avocado, mango, and rose.

The adult weevils vary in size and color markings. General color black, with white and yellow markings; head and snout black, pitted with white. The black markings on the elytra, or wing covers, are not constant. The lines run together, in many cases producing an irregular black surface. The white markings on the thorax and abdomen are also variable, many specimens of both sexes having been found in which these markings were lost or greatly modified. The male, as a rule, is much smaller than the female. They average about as follows: Female, length one-half to three-fourths inches; male, length one-half to five-eighths inches.

When this insect appears, spraying should be resorted to with arsenate of lead, 4 pounds to 50 gallons of water. If there is a great deal of scab in the groves it is recommended that a fungicide be applied with the insecticide. Bordeaux mixture may be used as such with arsenate of lead, since these two solutions mix readily and can be used as one spray.

In using Bordeaux mixture and arsenate of lead one should be sure that the scale insects are well under control before applying this combination insecticide and fungicide, as the Bordeaux kills all the beneficial fungi that prey upon the purple scale.

SMALL ORANGE-LEAF WEEVIL, OR "GREEN BUG."

The small orange-leaf weevil, or "green bug," was first noticed during the winter of 1908. It was found in the San Juan district and near Arecibo. It has been observed only in groves planted in sandy soils. Its life history has not been completely worked out.

In 1908 the insects appeared in January and February, and by the 1st of March all the beetles had disappeared. The eggs are laid in clusters between leaves, although in the laboratory they have also been found between a piece of paper and a leaf. The number of eggs in a cluster varies from 6 to 24.

The grubs, or larvæ, are footless. Color of head, brown; body, white, covered with rows of white hairs. There are four hairs on the last segment of the abdomen. The larvæ soon fall to the ground and feed on the roots of orange trees.

During 1908 this insect appeared in June during the blossoming period and was seen scarring the fruit.

The green adult beetle is a ravenous feeder, eating the orange leaves, especially the new growth.

The treatment is the same as for the orange-leaf weevil. Some have made it a practice to pick off the weevils by hand and find it more satisfactory than spraying, especially in small groves.

MAY BEETLE.

(*Lachnosterna* sp.)

This is a large brown beetle which works at night, coming up from its burrow at the base of the tree soon after dusk. The burrows are from 4 to 6 inches deep and usually under the trees that the beetles feed upon. The eggs are laid in these burrows and soon after they are hatched the young grubs commence to feed upon the roots of the trees.

The work of the beetles is more noticeable in young groves, especially where ground has been broken for the first time, as all the plants on which they feed have been destroyed and there is nothing but the orange left for them to eat.

The adult insects are often gathered by hand, men and boys being employed for that purpose. Arsenate of lead is used as a spray for these beetles, and it can be mixed with kerosene emulsion or with Bordeaux mixture.

The May beetle is a voracious leaf feeder. It generally appears during April, May, and June, or a little earlier than the orange leaf weevil.

The "caculo,"[1] or larva, of this insect is a large, white grub and feeds on the roots of the orange, sugar cane, and a number of the common grasses, causing a great deal of destruction. Often as many as 50 grubs have been taken from around the base of a single young orange tree.

When the caculos are present in great numbers, especially in newly planted groves, they eat the small roots, and sometimes girdle the taproots. In such cases the tree gradually turns yellow and dies unless it is promptly treated.

Remove the soil from the base of the tree, take out the grubs, and cut off any roots that are girdled; replace the earth and fertilize heavily, so that the tree may have plenty of nourishment for a fresh start.

ORANGE DOG.

This pest is the variegated caterpillar of a butterfly belonging to the genus Papilio, which makes its appearance during the summer. It has been found in the larval stage at the station during July and October. The caterpillars feed on the leaves of the orange, and if present in great numbers will cause a great deal of damage, as they are ravenous eaters. Hand picking is recommended where there are but few insects. At the station very satisfactory results were obtained by spraying the trees on which they were feeding with arsenate of lead, 3 pounds to 50 gallons of water.

[1] Caculo is the common name under which the grub of the May beetle is known in Porto Rico.

FIG. 1.—ANTS' NEST AT BASE OF ORANGE TREE.

FIG. 2.—INJURY TO FRUIT DUE TO ANTS. INJURY TO FRUIT DUE TO WIND.

BROWN ANT.

(*Solenopsis geminata.*)

Ants are always found where the white fly and the Lecanium scale are present. They attend these two insects to obtain the honeydew secreted by them. When their supply of food is suddenly cut off, ants often attack the young, tender shoots of the orange, eating them at the point where they join the branches. They also eat young, tender leaves, and a few cases have been observed where they had cut holes in ripe fruit. Under these conditions much damage is done. They also carry sand up around the base of the trees, and when there is scant food supply they gnaw the bark of the tree where it is covered by their sand houses. (Pl. I, fig. 1.) Often when pineapples have been removed from between rows of orange trees the ants attack the latter in great numbers, scarring the trees, eating young, tender shoots, and cutting holes in the fruit.

When they appear in this way they must be killed by spraying. The simplest and most inexpensive spray that has been used is carbolic acid and soap. The formula for this emulsion will be found in the section under "Formulas." In spraying for ants it is advisable to locate the nests and destroy the ants by spraying down into them. A second spraying is always necessary the following day, as many of the ants are away from their nests at the first spraying. In spraying large nests it is a good plan first to spray a circle around the nest and then to spray directly into it, thus making it impossible for the ants to crawl out and insuring their being killed by the emulsion.

WOOLLY WHITE FLY.

(*Aleyrodes howardi.*)

This white fly, found in Porto Rico, is not the common citrus white fly of Florida, although the latter has recently become established there. It feeds upon the guava and orange, and has been determined through the kindness of Dr. L. O. Howard as *Aleyrodes howardi.*

It appears on the underside of the leaf and is usually attended by ants, which feed upon the honeydew which it secretes. The eggs look like little spots of dust on the underside of the leaf. In a short time these develop into larvæ, which spin white, silky mats. It is during this stage that the ants attend them. Later the larva transforms into a pupa, which develops into a tiny insect resembling a minute fly.

It is recommended that a strong emulsion of kerosene be applied, about one part of stock emulsion to six of water, a second application following in about two weeks.

RED SPIDER.

There exists on the island a little red spider which feeds upon the essential oils of the orange. The leaves and fruit become rusty in appearance when this oil is removed. The spiders prefer the under or shady side of a fruit or leaf on which to feed, and for this reason oranges sometimes become rusty on one side only. The eggs are laid on the underside of the leaves, along the midrib. They are pinkish-white in color and the empty eggshells resemble minute pearls. The young are light yellow, later turning red. The adults can be readily seen with a magnifying glass crawling over the leaves.

The adult is readily held in check with sulphur sprays or with any soap or kerosene spray which will kill soft-bodied insects. The eggs are not so easily killed, and it is therefore advisable to spray a second time two weeks later.

Sulphur may be applied dry by throwing it into the trees or by the use of blowers. This should be done in the morning, when trees are wet with dew, or immediately after a rain.

These insects are most prevalent during extended periods of drought. During the rainy seasons they are held in check by the rain, as they are washed to the ground and destroyed. They were first observed in the station grove in 1908.

RUST MITE.

During the spring of 1909 the rust mite was noticed for the first time on the orange, grapefruit, and lemon. This mite closely resembles the Florida species and probably is identical with it. It is small, can not be seen with the naked eye, and it is only by careful search with a strong glass that it can be found. Its habits are the same as those of the red spider. The eggs of the rust mite are not always laid on the underside of the leaves, but are often found on the surface and on the fruit. They are silvery in appearance and, being minute, are hard to distinguish from the oil cells. The leaves and fruit of a tree infested with rust mites are of a dirty green color, caused by the breaking down of the oil cells and the presence of the cast-off skins of the insects, which are whitish.

The adult mite is of a lemon color; the head is three times as broad as the body, there being a gradual tapering from the head backward. The adult has two pairs of legs on the anterior portion. The rust mite is not active like the red spider, it being very difficult to determine if they even change their position.

Treatment for the rust mite is the same as for the red spider.

PURPLE SCALE.

(*Lepidosaphes beckii.*)

The purple scale is present in all cultivated and wild groves of this island, and is the most serious orange pest in Porto Rico. It appears not only on the trunks and branches of the trees, but also on the leaves and fruit. It is on the young branches and fruit that most damage is done; the former are often killed and the latter so badly spotted with scales that it has to be washed before shipment.

The life history is as follows: The eggs are very small, pearl white, usually from 40 to 80 in number. The laying continues over a period of 8 to 11 days; the first eggs hatch before the last are laid. Conditions often so affect the hatching of the eggs that the hatching period may extend to 16 or 18 days. Some eggs kept at the laboratory did not hatch until the eighteenth day, whereas others hatched in 8 days under the same conditions. This delay in hatching makes spraying less effective.

The young usually crawl from 12 to 24 hours before settling down; after this they insert their sucking mouth parts into the epidermis of the leaves and develop a covering consisting of white, waxy threads. Under this coat or covering they remain for about two weeks, then form a second covering; at the end of three weeks the male scales can be distinguished from the females.

The adult male appears in five weeks and can be seen, with the aid of a glass, crawling over the leaves and branches. At this period the females are not full grown, as it takes seven weeks for them to develop. At the end of this time they are often found with eggs. The life cycle of the females requires from 8 to 9, and in some cases 10, weeks. The adult male scale is much smaller than the adult female, and both are reddish brown to dark purple in color. The adult female resembles a minute oyster shell. For this reason it is often called the "oyster-shell scale," but it should not be confused with the oyster-shell scale of the North, as they are two distinct species.

The purple scale in the Tropics has no definite seasons for producing its young. At the station and in various groves of the island crawling young have been found at all seasons of the year. On account of its irregular appearance it is very difficult to eradicate by spraying. The adult female scales and eggs are not killed by any of the emulsions heretofore used by the planters. It is now recommended that those who are using kerosene and crude-oil emulsions repeat their spraying in about 21 days; this leaves ample time for the females which escape the first spraying to deposit their eggs and for the young to hatch out.

WHITE SCALE.

(*Chionaspis citri.*)

These insects are generally found on the trunks and branches of old trees. The infestation usually starts at the base of the trees and gradually works up among the branches and often into the young twigs. However, it very seldom spreads in this way on trees which have been treated for the purple scale. The infestation is not so rapid as with the purple scale, even though it is not attacked by as many (or the same) fungi as prey upon the purple scale. There is, however, a black fungus that parasitizes the white scale, but in cultivated groves this is rather slow in spreading. (Pl. II, fig. 1.)

Life-history studies of this scale made at the station show that it requires the same length of time to develop as does the purple scale. The color of the male is white, with three parallel ridges extending longitudinally. The female is reddish-brown in color and resembles the purple scale in general appearance. The larvæ are yellowish-red and when crushed leave a yellowish-red spot. The crawling young are pinkish-red, and with a magnifying glass can be seen crawling over the trunk and large branches of trees.

The most effective emulsions are kerosene with carbolic acid, 1 part of the mixture to 5 of water, and crude oil with carbolic acid, 1 part of the mixture to 15 or 18 of water. The directions for making these emulsions will be found on page 28 of this bulletin.

In groves that have good windbreaks this scale is held in check by fungi, and spraying is not necessary.

FLORIDA RED SCALE.

(*Chrysomphalus aonidum.*)

The Florida red scale is quite prevalent in the citrus groves and is generally found on the leaves and fruit of the orange and lemon. This insect does not spread as rapidly as the two scales previously mentioned, but when found on the fruit it is very difficult to remove.

It develops in about eight or nine weeks. The crawling young are yellow and settle down very soon after they come from under the mother scale. Their first covering is of a slate color, which changes in a few days to red. In about three weeks the sexes can be distinguished, and in five weeks the males are full grown and, with the aid of a magnifying glass, can be seen crawling over the surface of the leaves. At this period the females are not fully developed. The young begin to come forth in about 7 weeks and continue to appear for from 9 to 11 days.

The adult male scale is much smaller than the female. It is round, with a small flange on one side resembling a tiny red cap. The

Fig. 1.—Black Fungus on White Scale (Chionaspis citri).

Fig. 2.—Red-headed Fungus (Sphærostilbe coccophila) on Purple Scale.

female is red also. It is perfectly circular and without the flange. The red-headed fungus (*Sphærostilbe coccophila*) has been found preying upon this scale.

Treatment for the red scale is the same as for the purple scale.

HEMISPHERICAL SCALE.

(*Saissetia hemisphærica.*)

This insect, generally found on the small branches and leaves and occasionally on the fruit, is attended by ants, which distribute the young from place to place (Pl. III, fig. 1). It attacks many of the ornamental plants also, but is not considered a serious pest, as it is readily held in check by one or two sprayings of kerosene emulsion. This species is preyed upon during the rainy season by a white fungus (*Sporotrichum* sp.) (Pl. III, fig. 2). The adult is brown and almost hemispherical, while the young is yellowish, flat, and ridged.

BENEFICIAL FUNGI.

Several species of beneficial fungi have been found preying upon the purple and white scales, namely, the red-headed, the white-headed, and the black fungi.

The red-headed fungus (*Sphærostilbe coccophila*) appears in the Bayamón district, and is more prevalent there than the white-headed fungus.

The white-headed fungus (*Ophionectria coccicola*) has been observed in a great number of groves in the Pueblo Viejo district, where it appears in greater numbers than the red-headed fungus. Both these fungi prey upon the purple scale.

There are several species of black fungi that prey upon both the purple and white scales. The species that prey upon the purple scale spread very rapidly, whereas those that prey upon the white scale spread very slowly.

The fungi should be carefully watched and may be taken as an indication as to whether the grove is sufficiently protected by windbreaks. It must be remembered that fungi thrive only under moist conditions, as the spores can not reproduce in exposed groves which are constantly being dried and beaten by the winds.

METHODS OF INTRODUCING BENEFICIAL FUNGI.

In Florida, for the past few years, a great deal of attention has been paid to the work of beneficial fungi. It has been demonstrated that such fungi can be introduced into groves if they have a reasonable amount of wind protection.

Porto Rico has the same beneficial fungi that occur in Florida, and although the planters have never made special effort to introduce

them, there are certain groves in which the scale is held in check thereby. The following methods for introducing fungi are taken from Bulletin 94 of the Florida Station:

First method.—Select a tree which is thoroughly infested with scale and tie a twig in it which has fruiting spores of the red-headed or the white-headed fungus. The twig should be tied well up in the tree, but not so high that the wind will dry out the fungus. If there is plenty of fungus three or four twigs may be put in the tree so that the infection will be more rapid. The rain and dew wash the spores down the trunk and branches which are covered with scale and infect them. Fungi do not work as rapidly in young trees as in old ones on account of the lack of moisture.

Second method.—By this method the leaves containing fungi are introduced into trees which are infested with scale. The leaves should be tied or pinned to the infested parts so that the rain and dew can distribute the spores. Where plenty of material can be obtained it is better to use the first method, as the twigs do not dry out as quickly as the leaves.

Third method.—This method consists of the introduction of trees which are infected with beneficial fungi. The method is practical, but the infection is not so rapid in the groves as when twigs are used in individual trees.

Fourth method.—Make a culture by placing a number of fruiting spores in water and use as a spray for the scale-infested trees.

This spraying should not be done with a pump which has previously been used for spraying Bordeaux mixture or lime sulphur, as these fungicides will destroy the beneficial fungi. It is also well to use a pump which does not have brass fittings; a galvanized-iron sprayer is best.

The black fungi which prey upon the purple and white scales can also be introduced by tying branches containing them into trees infected by scale.

WINDBREAKS.

Three important questions must be considered when purchasing land for planting: (1) Suitable soil; (2) shipping facilities; and (3) protection from wind.

This last question is by no means the least important, owing to the prevailing strong winds from the northeast. These winds are so constant that it is almost impossible to start a grove unless it is protected. If there are no natural windbreaks, artificial ones will have to be established.

Wind-swept groves can be easily distinguished from protected ones. The trees in the former have a peculiar tired appearance; the branches are blown to one side and covered with scale; the bark looks dead and new growth becomes twisted out of shape, and in a few months looks like the old.

As all fungi thrive only under moist conditions, the beneficial kinds, therefore, never appear in these groves on account of the constant action of the wind on the trees.

There are certain groves on the island which have been planted for three years and even yet look as if they had just been set out. Almost adjoining these groves are others, planted at the same time

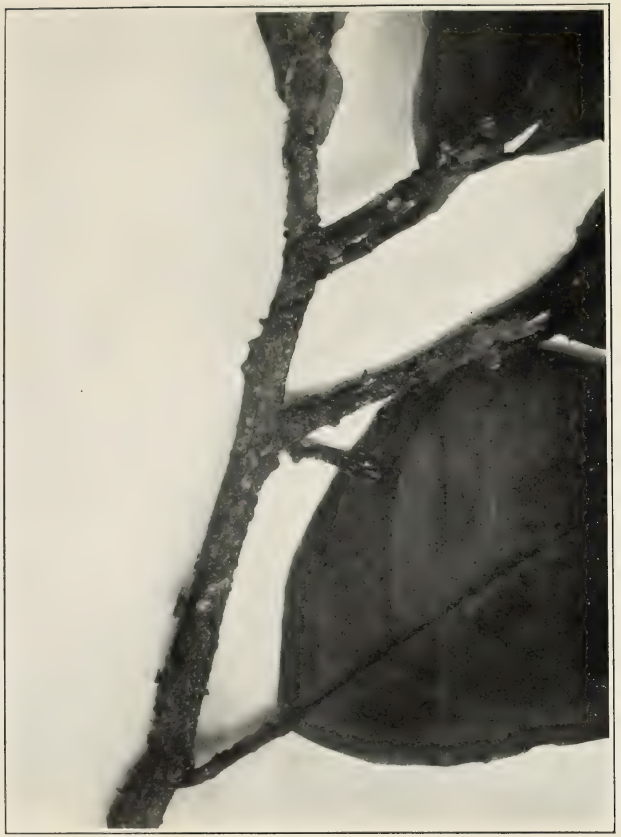

FIG. 1.—HEMISPHERICAL SCALE (SASSETIA HEMISPHÆRICA).

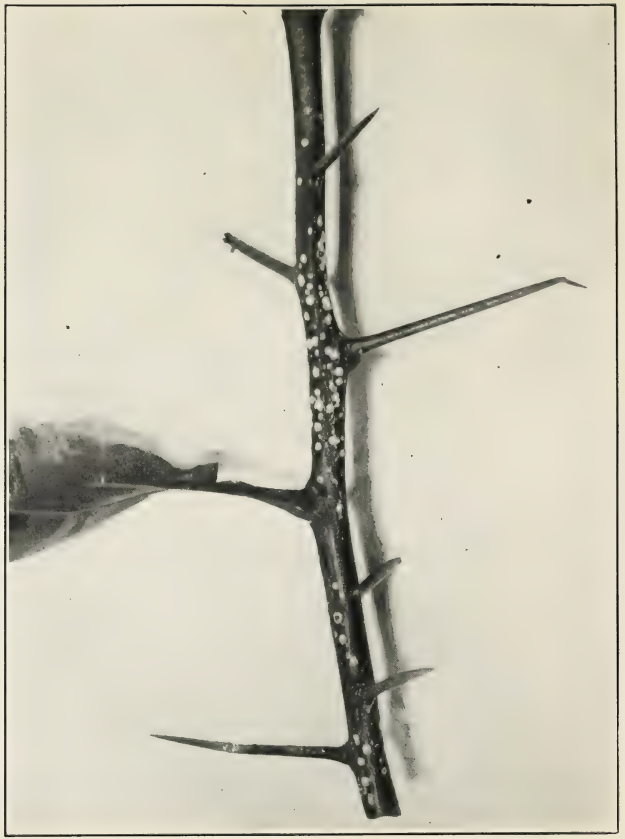

FIG. 2.—WHITE FUNGUS (SPOROTRICHUM SP.) ON HEMISPHERICAL SCALE.

FIG. 1.—PERMANENT WINDBREAK, TIMBER.

FIG. 2.—PERMANENT WINDBREAK, MANGO TREES.

and in the same kind of soil, which look healthy and are producing fruit. There is only one explanation for this difference and that is that on one side of the road brush has been allowed to grow which acted as a windbreak.

One of the best examples of the effect of a natural timber windbreak is the Plantaje grove at Palo Seco. (Pl. IV, fig. 1.) This grove until 1908 did not need to be sprayed for the purple or white scale. Since then some of the breaks have been taken out and the scale has begun to come in.

Another grove near Manati shows the effects of wind protection from the prevailing winds by hills, and spraying has not been necessary for two years.

Many planters think that the first row of trees on the windward side will soon protect the other trees, and give this as a reason for not planting windbreaks. This is sometimes true, but a great deal of time is lost in waiting for these trees to grow enough to afford protection.

There is not a grove on the island that does not need in some part more protection from wind than it has at the present time. There are always certain parts of the orchard which appear older than others, though if the grower will examine his notes he will find that the trees are all the same age and that there are windbreaks in localities where the trees are more fully developed; furthermore, that not as much spraying is required as in the unprotected parts.

There are two classes of windbreaks: Natural, such as hills and forests, and artificial, such as bamboo, mango, brush, sugar cane, pigeon peas, and bananas. There are two kinds of artificial windbreaks, the permanent break and the temporary. Permanent breaks are set out along the outer edges of groves for a permanent protection to them. The temporary breaks are set out between the rows of trees and are removed as soon as the trees afford protection for themselves.

Bamboo is one of the best quick-growing permanent windbreaks. One year after planting it serves as a good protection for young trees. It should be planted during the wet season, using cuttings about 2 feet long. Good results have been obtained by laying whole sticks in a foot trench, burying them with 4 inches of earth and covering with a little trash to keep the soil from drying out.

The mango is usually set out as a permanent break, but on account of its slow growth it yields very little protection for the first three or four years. (Pl. IV, fig. 2.) In planting mangoes it is best to omit at least one row of citrus trees and cut a deep ditch between them and the mangoes, so that the roots of the latter will not extend into the grove. It is advisable to head the mangoes low, so that it will act as a break as soon as possible. Some varieties of Indian mangoes are

excellent and far superior to the native fruit. There is no fiber and the turpentine taste is wholly absent.

Permanent windbreaks of native mangoes can be planted and then inarched or topworked to the Indian. The best success has been had at the station with inarching. Some of the 4-year-old inarches are now bearing their first crop of fruit. If the mango is set out and grafted, it not only affords a fine windbreak, but may become a source of revenue.

In planting brush land in sections where the winds are strong it is advisable to leave a strip of uncut timber 20 feet wide every 300 to 400 feet to act as natural windbreaks. The distance between the strips should vary according to the land. When the land slopes away from the wind the breaks should be farther apart.

Pigeon peas are used with success in young citrus groves as temporary windbreaks. (Pl. V, fig. 1.) This plant gathers nitrogen and thus answers two purposes—acting as a windbreak and returning nitrogen to the soil. The plant lasts about two years and then dies. However, the old stocks may be cut back and new sprouts allowed to come up. The trash made by the leaves and small branches adds a great deal of humus to the soil. It is not as ravenous a feeder as the banana.

Bananas are also used as temporary breaks. (Pl. V, fig. 2.) They are very quick growing and afford excellent protection to young trees. Sometimes they are a good investment, as the crops often pay for the cultivation. There is one disadvantage in the banana as a windbreak. It is a gross feeder, and if not watched sends its roots into the grove and robs the young trees of their nourishment, and unless they are very heavily fertilized their growth will be retarded after the first year and a half. This may be overcome by heavy application of fertilizers or by plowing a deep furrow along the row of bananas, thus cutting the roots so that they will not extend into the grove.

Temporary windbreaks should not be removed from young groves all at once. It is best to remove them gradually, especially those of banana and pigeon pea. Alternate rows should be removed, leaving some protection, especially when the permanent break is not sufficiently large to protect the whole grove. When it is found that some areas still need protection, they should be left with a windbreak, even if the uniform appearance of the grove is marred. The trees thus protected will soon attain the size of the other trees.

SCARRED FRUIT.

Insects are not wholly to blame for all disfigured and discolored fruit. The constant chafing of a young orange, when a week or two old, against a leaf will produce a scar in the mature fruit; scars are also produced by the fruit hitting thorns. Many fruits, especially

FIG. 1.—TEMPORARY WINDBREAKS, PIGEON PEAS AND SUGAR CANE.

FIG. 2.—TEMPORARY WINDBREAKS, BANANAS AND PIGEON PEAS.

those on the lower branches, are injured by animals or by cultivators, as it takes only a very slight knock to bruise a young orange.

A number of observations were made of scars caused by the chafing of the wind, and it was found that there was a marked difference in the amount of scarring on the two opposite sides of the tree. In one case the windy side showed 23 scarred to 234 unscarred fruits, while the lee side of the same tree showed 7 scarred to 210 unscarred. This scarring was caused by the constant rubbing of the fruit against leaves or small branches. The scars appeared on the very young fruit and looked dark, more like a bruise. As the fruit ripened the bruise hardened, lost its green color, and appeared silvery. (Pl. I, fig. 2.)

The scars made by ants are altogether different from those produced by the wind, the former being deep-seated and caused by the insects removing some of the epidermis and eating into the fruit. (Pl. I, fig. 2.)

There are several species of ants which feed upon the nectar secreted by the orange blossoms. The brown ant and the little black ant are especially fond of the nectar. These two species have been seen working in the blossoms in the early morning, sipping the nectar, and toward noon, when it has been exhausted, attacking the unopened blossoms, or young fruit. Some cases have been observed where the green calyx leaves were eaten so badly that the fruit dropped. In other cases the pistil was chewed off and the fruit never developed. Again, the brown ant sometimes cuts holes in the young fruit.

Ants do more damage during years when there is a scanty bloom or when the bloom extends over a prolonged period, as they eat the fruit when not supplied with sufficient nectar.

Scars made by the small orange-leaf weevil are of the same character as those made by the ants, only they are much larger.

Mites and spiders produce discolored fruit. They pierce the oil cells with their beaks and remove the oil, causing the fruit to turn to a brown or russet color.

Fruit rust is also caused by a fungus which destroys the oil cells.

During the bloom of February, 1909, it was found in one grove that from 13 to 45 per cent of the young fruit which had just formed was scarred by ants and other insects. A few experiments were carried on to see whether this scarring could be stopped by spraying. Kerosene emulsion made with crude carbolic acid, 1 part to 17½ parts of water, was applied to trees in full bloom; the spray was forced down into the blossoms. Four days later the new fruit which had just formed was examined and showed only 5 per cent scarred, while fruit taken from the check rows adjoining showed from 45 to 55 per cent scarred.

The second lot of scars was caused by sucking insects and appeared as if a sharp pin had been drawn across the fruit. The skin was broken and the oil cells were destroyed. The scars were probably caused by thrips, which were present in these trees in great numbers.

NOTES ON SPRAYING.

Spraying not well done is but little better than no spraying at all. Every part of the tree must be covered with the emulsion, as the parts left untouched become sources of immediate infection. In spraying for scale, for example, it is not the amount of emulsion used that does the work, but the emulsion that actually covers the scale and penetrates its covering.

Trees can be sprayed more easily and much better work can be done immediately after pruning, as the operator of the nozzle can hold the extension rod into the center of the tree and direct the spray outward and at the same time cover the underside of the leaves. If the trees are headed low and the centers are well opened not so much of the emulsion is wasted, and the work can be done more quickly and better.

In spraying trees it is best to commence at the base and work up, spraying the underside of the branches and leaves first, gradually working toward the top. If the trees are not too large with open centers, and the operator has a long extension with a one-fourth elbow connection for the nozzle, all the spraying may be done from one side of the tree. The one-fourth elbow is very useful in this work, as it not only enables the operator to reach the underside of the trees, but also to spray the tops by raising the rod above the tree, thus directing the spray downward without adjusting the nozzle. Pains should be taken to cover every spot, especially the underside of every leaf, as many of the insects are found there.

Where strong oil emulsions are used it is recommended to hill up the earth around the trees previous to spraying, and afterwards to clear the earth away so that the oil will not remain around the trunk and soak down to the roots. In sandy soils the earth may be thrown up quickly by the operator immediately preceding spraying, but where the soil is firm a man or boy should precede the sprayer to do this, as it will save time. The soil should be removed as soon as the spray stops running down around the base of the tree.

COVERING FOR OPERATORS.

Operators of sprayers need something to protect their clothing, as it is impossible to spray trees against the wind without getting wet, and furthermore, it is not likely that the work will be done thoroughly under such conditions. The spraying apparatus should, therefore, be provided with a long extension rod which permits the

operator to stand at one side and direct the spray into the tree. He can also protect himself with a coat made by cutting three holes into some light-weight cloth, such as flour sacking or gunny cloth from sacks, which answers the purpose very well.

SPRAYING MACHINERY.

Sprayers are divided into two classes, hand and power sprayers. At the present time there is only one power sprayer on the island, all work being done by barrel and knapsack pumps. The most common sprayer in use is the barrel pump, mounted on a two-wheel cart and drawn by hand or by a mule. Barrel pumps are more satisfactory when fitted with extension rods and two hose each from 25 to 30 feet long. Much time and labor are saved by using long hose, as it is much easier to draw a line of hose around a tree than it is to haul a spray cart around it; and as spraying has to be suspended while moving the cart, much time is lost. A two-wheel cart drawn by a mule is a good arrangement for orange spraying, as it does not take up much room and the driver does the pumping.

The knapsack and small compressed-air pumps are very useful in spraying trees for ants or pineapples for mealy bugs; also for use in gardens and on trees up to the age of 1½ years. As the trees become larger they require a greater amount of emulsion to wet them thoroughly and a great deal of time is consumed in filling a knapsack or small compressed-air pump, therefore a barrel pump at this stage is more satisfactory.

Extension rods and hose attachments are also a great addition to hand pumps. One objection to the small compressed-air pump is the lack of an agitator, and under these conditions the ingredients of the spray are liable to separate from each other; this is especially true in using emulsions which contain arsenate of lead.

Power sprayers are classed according to the kind of power used in running the pumps, such as gasoline, steam, compressed-air, and geared sprayers.

Geared sprayers are those which receive their power from a series of gears and chains which connect the pump with the running gear of the wagon. These sprayers are used for garden truck, cotton, grain, and grapes, where the wagon can move along continuously. This arrangement is not as satisfactory for spraying in orange groves, as the trees are planted so close together that sufficient power would not be generated by passing from one tree to the next. It might be possible to obtain sufficient power to spray alternate trees, but as all spraying in Porto Rico is done with trees in foliage, it requires much more liquid than for trees of the same size which have shed the leaves.

Of the various power sprayers on the market the gasoline engine type appears to be most practical, especially for spraying fruit trees.

AGITATORS.

Every pump should be supplied with a good, strong agitator to give the best results.

There are two classes of agitators for barrel pumps; the most satisfactory kind is the one which consists of two paddles attached to an iron rod, which is connected with the pump handle; thus at every stroke of the pump the paddles are in action keeping the emulsion thoroughly mixed.

The best agitators for power sprayers are of the rotary type. They are made in the form of a propeller and connected with the engine. As soon as the engine is started the emulsion is being thoroughly mixed. Dasher agitators are not as satisfactory as the propeller type. They are more liable to give out, as there is a jerking motion caused by their imperfect connections with the engine.

EXTENSION RODS.

Extension rods enable the sprayer to do much better work. They are generally used on barrel sprayers and power outfits, but are also practical when used with knapsack or bucket pumps.

The length of the extension rods to be used should vary according to the kind of spraying to be done. Bucket and knapsack pumps for spraying young trees 5 to 6 feet high should be fitted with extension rods 3 feet long. Barrel pumps should be equipped with extension rods and the length should depend upon the size of the trees to be sprayed. For trees 10 to 12 feet high use a 6 to 8 foot extension rod, while trees larger than this should be sprayed with a 10-foot rod.

Extension rods made of one-fourth inch brass tubing covered with bamboo are very light and not cumbersome. All rods should be supplied with stopcocks, which enable the sprayer to shut off the stream and examine his work. Homemade extension rods can be made with a piece of one-fourth inch pipe threaded at both ends so that one end will fit the stopcock and the other the nozzle.

For very large trees spraying towers are recommended. These are often built on top of a tank wagon. They are usually supplied with power outfits and are made in sections, so that they may be removed when not in use.

NOZZLES.

There are two general types of nozzles, the Bordeaux nozzle, which produces a fan-shaped spray, and the Vermorel, which produces a conical spray that breaks up into mist. The spray from a Bordeaux nozzle carries much farther than the Vermorel before breaking up.

Both types are used on the island, but the Vermorel is used almost exclusively for spraying with oil emulsions. The fine mist produced by this nozzle is preferred when using oil, as it takes only a small amount of it to cover the insects. In the form of a fine mist the emulsion is more evenly distributed.

Vermorel nozzles are made in two sizes; the small size is made with disgorgers whereas the large size is made without them. The large nozzles are more suitable for barrel pumps and power sprayers, and the smaller ones for knapsack pumps. In spraying small trees the small nozzle is more satisfactory, as little emulsion is lost. Large nozzles should be used only where there is sufficient power in the pump to produce a fine mist.

Drench spraying is not as satisfactory as mist spraying, as a great deal of the solution is lost.

INSECTICIDES AND FUNGICIDES.

INSECTICIDES FOR BITING INSECTS.

PARIS GREEN.

Paris green can not be used as effectively here as in the United States, on account of the heavy tropical showers which occur nearly every day during the rainy season. In some of the drier parts of the island this insecticide with air-slaked lime can be used with good results as a dust spray.

ARSENATE OF LEAD.

Arsenate of lead has been introduced, and at the present time it is taking the place of Paris green; it is not readily washed off by the rains, and it can also be used without any danger of burning the foliage. The formula is as follows:

Arsenate of soda (50 per cent strength)	ounces	4
Acetate of lead	do	11

Dissolve the arsenate of soda in 2 quarts of water and the acetate of lead in 4 quarts of water, using wooden vessels. Pour the solutions together and add 10 to 50 gallons of water. The white precipitate formed is arsenate of lead, which remains in very fine particles and is held in suspension much longer than Paris green. It can also be used with Bordeaux mixture or with kerosene emulsion.

ARSENITE OF LIME.

Formula for preparing white arsenite of lime is as follows:[1]

White arsenic	pound	1
Crystal sal soda	do	4
Water	gallon	1

[1] U. S. Dept. Agr., Farmers' Bul. 127 (rev. ed. 1908).

Mr. Marlatt says:

Place the above ingredients in an iron vessel, which is to be kept exclusively for this purpose, and boil for 20 minutes or until dissolved. To 40 or 50 gallons of water a pint of this stock solution and 3 to 4 pounds of freshly slaked lime are added. This excess of lime not only takes up any free arsenic but by its distribution on the foliage enables one to determine how well the spraying has been done. This formula has been thoroughly tested and used now for many years, and is fully as efficient as any other arsenical and far cheaper. Chemically it is arsenite of lime. The soda is used to hasten the process and to insure the combination of all the arsenic with the lime. The greatest care should be exercised in preparing the stock mixture, and afterwards it should be plainly labeled to prevent its being mistaken for some other substance. The only objection to its use is the necessity of handling the poisons in its home preparation.

INSECTICIDES FOR SUCKING INSECTS.

A great number of contact poisons are being used in the island for destroying the various scale insects. Among the most promising are the miscible oils, crude petroleum, kerosene emulsion, and lime-sulphur wash.

Many of the best emulsions have been condemned because they were not made exactly according to the formula. This has been especially true of the crude petroleum and kerosene emulsions. Not enough attention has been paid to the making of these emulsions. Often in ordering the ingredients the specifications are not clear, and as a consequence the goods that arrived are not just what was desired. Imperfect emulsions, in which the oil separates again from the water after being diluted, result from the use of hard water and from shortening the time required in mixing. Rain water should be used in making emulsions.

MISCIBLE OILS.

Miscible oils are concentrated solutions of ingredients which have insecticidal properties to which it is simply necessary to add water to form the emulsion. They are usually handled commercially and have become one of the most promising scale destroyers. A manufactured miscible oil is used by some of the fruit growers with good results, having proved itself to be one of the best scale remedies that has yet been tried. The large growers can not use it, however, as it is too expensive. Tests made here show that a strength of 1 to 25 not only destroys all the crawling young and those bearing the first covering, but also a great number of females with eggs. This emulsion has been used with good results on orange and grapefruit. At a strength of 1 to 20 some leaves dropped, but these were incrusted with scale or from badly infested branches. Homemade miscible oils were experimented with during 1908 and a number of formulas

have been tried. The most promising are those made with crude petroleum and rosin oil. These give very stable emulsions and their destructive power is very high.

Miscible oils have many advantages over the kerosene and crude-oil emulsions. After the soap is once made no more heat is required to make the stock emulsion or the various dilutions of the stock emulsion. Only one-third of the soap is heated and the other two-thirds is made up of kerosene and water. The time required for making the soap is about an hour.

If properly made they should not have any free oil on the surface when mixed with water. Emulsions made with kerosene do not require as much attention as those made with the heavier oils, such as rosin, paraffin, or crude oil.

On April 21, 1908, a number of experiments were made with the formula recommended in Bulletin 79 of the Delaware Agricultural Experiment Station. The trees were incrusted with scale at that time, but by March, 1909, they were absolutely free from scale. The scale did not immediately drop, but the trees have been cleaned by the rains and do not appear as if they would need spraying during the coming season. No ill effects from these sprayings can be seen. The trees have had their usual amount of new growth and blossoms.

There is always a small percentage of leaves that drop, but they are usually the ones which have been covered with scale and have become weakened by the constant action of it. The loss of such leaves is not detrimental, as it is better that they be removed. Healthy, vigorous leaves are not injured. Similar results have been obtained with paraffin and crude oils.

These sprays should be applied with a nozzle that gives a very fine mist. The oils are very penetrating, and for this reason a smaller amount of emulsion is needed than of the old kerosene emulsion sprays.

Before the stock emulsion is taken from the barrel the whole mixture must be thoroughly stirred, as the oils are liable to separate upon standing.

For stirring the emulsion a piece of board about $4\frac{1}{2}$ feet long and 4 inches wide, to the base of which has been nailed a strip of board 10 inches long by 4 inches wide, has been found convenient. By using such a paddle the emulsion at the bottom of the barrel, which is thicker than that at the top, is raised and the whole mass becomes uniform. It is always advisable to test the stock emulsion before taking any out for spraying. If any free oil is found, add a little water and after thoroughly stirring test it again. Continue this until a perfect emulsion is obtained. If this testing is not done, an emulsion with free oil is liable to be sprayed upon the trees, which will

kill some of them. These emulsions are rather stable, and after one has determined the amount of water necessary to make a complete emulsion it very seldom varies. Where spraying is being done on an extensive scale the stock emulsion may be placed in the bottom of the spray tank and the water slowly added, stirring the whole until about half of the amount of water has been added, then the rest of the water may be added and the spraying begun.

The dilutions of all formulas have had to be changed, as all spraying in Porto Rico is done on trees with foliage. The dilution of crude oil formula set forth in Bulletin 49 of the Connecticut Storrs Agricultural Experiment Station was changed from 1 to 15 to 1 to 25, the latter strength having exceptional killing powers. It not only kills the young purple scale, but also the females with eggs.

The same can be said of emulsions in which paraffin and kerosene oil are substituted for the crude oil. The miscible emulsions made with heavier oils do not evaporate as quickly as those made with lighter oils, and for this reason their killing power is extended over a longer period. It has often been observed that the old scales seem to retain a certain amount of oil which is later on set free by the rains. This seems to be sufficiently strong to kill any crawling young whose mother has escaped being killed. The oil particles of these emulsions made with kerosene were so finely divided that they could not be seen with low powers of a compound microscope.

All the work done with these emulsions has been on young trees which were not fruiting. They will be tested on trees with fruit to determine whether they cause the young furit to drop or whether they produce any discoloration.

Directions for making miscible oils.—There are three steps to be taken in making miscible oil emulsions before the emulsion for spraying is obtained. First, the cooking of the soap and the adding of the kerosene and water. Second, making the stock emulsion out of the soap solution and various oils. Third, diluting the stock emulsion for spraying.

The soap solution should be made in the open air or under an open shed, as the mixture is inflammable when it reaches 300° F. It is also advisable to make the soap solution in a receptacle that is large enough to allow plenty of room for boiling. When the soap reaches 240° F. it begins to boil and continues to boil very violently until it reaches about 280° F. During this time the mixture foams and increases to at least double its volume. It is, therefore, very necessary that the receptacle be sufficiently large. When the soap reaches 300° F. it should be removed from the fire and the kerosene and water added. First, pour the kerosene in slowly, thoroughly stirring the mixture; allow this to cool a little, then add the water. It is better

to let it cool until the soap plus the kerosene is below 212° F. The following formula is used in making the soap solution:[1]

Menhaden oil	gallons	10
Carbolic acid	do	8
Caustic potash	pounds	15
Heat to 300° F., and then add:		
Kerosene	gallons	14
Water	do	22

In making the soap it is well to have the kettle covered with boards with a hole in the center through which a thermometer can be placed to take the readings. It does no harm if the soap reaches 310 or 315° F., but it is not safe to continue the boiling after the soap has reached 300° F., as it is more liable to take fire. After the soap solution is completed the fire can be drawn and the mixture placed in a barrel, after which the kerosene and water are added. The soap should be slightly ropy, but should run readily and not separate upon standing. A half barrel of this soap has been left standing for six months without undergoing any change.

Stock emulsions are made by the following formula:[2]

Soap solution	gallons	8
Crude oil	do	18
Rosin oil	do	4
Water	do	3
Or more if needed.		

This formula does not state definitely the quantity of water necessary to obtain an emulsion free from oil, as the amount to be used often varies. After the stock emulsion has been thoroughly mixed try a few drops in a glass of water, and if no oil appears the emulsion is ready to be diluted with the water for spraying. It is recommended to use 1 gallon of the stock emulsion to 25 gallons of water for trees without fruit.

KEROSENE AND CRUDE-OIL EMULSIONS.

Kerosene emulsion was one of the first sprays to be used by the fruit growers on the island. The results from one spraying with a solution 1 to 5 parts of water have not been satisfactory, only the crawling young and those bearing the first covering being killed.

Crude oils have given better results. This oil does not evaporate as readily as the refined or lighter oils, therefore remaining on the trees for a longer period and killing more scale. A smaller percentage of oil is required in the crude-oil formula. These emulsions break down more quickly than the kerosene emulsions, and for this

[1] Delaware Sta. Bul. 79.

[2] Connecticut (Storrs) Sta. Bul. 49. Modified by increasing the amount of water used.

reason are not used to so great an extent. It has been shown by experiments that the destructive power of crude-oil emulsion, 1 to 15 or 18 parts of water, is equal to that of kerosene emulsion 1 to 5.

While the price of these two oils is the same, the kerosene makes a more expensive emulsion than the crude oil, as it is not so highly diluted, this difference in the cost of the two emulsions being about 1 cent per gallon.

KEROSENE EMULSION.

Kerosene emulsion made with whale-oil soap is one of the oldest insecticides in use. It is not as difficult to make as the crude and miscible oil emulsions. It is not, however, as effective in controlling scale, but as it is easily made and does not separate it is still used by many fruit growers. The formula is as follows:

Kerosene	gallons	2
Water	do	1
Whale-oil soap	ounces	8

Put the kerosene oil in a spray pump. Dissolve the soap in the water by boiling and pour the solution into the oil; mix the whole by pumping for about 10 minutes, directing the stream back into the pump. If a large quantity of the emulsion is being made, it should be pumped longer. A creamy mixture should be obtained, which will hold up from two to three weeks.

KEROSENE AND CRUDE-OIL EMULSIONS WITH CRUDE CARBOLIC ACID.

During 1908 crude carbolic acid was used in combination with both crude-oil and kerosene emulsions. These emulsions were tested microscopically and appeared very different from the emulsions made without the crude carbolic acid. The oil particles are more finely divided, in some cases their diameter being only one-third to one-fourth the size of those in emulsions made without the carbolic acid. The killing power of these emulsions is greater than those made without carbolic acid, and they are more stable. Very little, if any, free oil could be found, even after the emulsion was allowed to stand several hours.

It seems quite possible that the carbolic acid will prove beneficial as a fungicide, but not to such an extent as the sulphur in the lime-sulphur mixture. Crude carbolic acid varies greatly in strength.

The formula for kerosene emulsion containing crude carbolic acid, 100 per cent (dark), is as follows:

Kerosene	gallons	2
Water	do	1
Whale-oil soap (hard)	pound	½
or—		
Whale-oil soap (soft)	quart	1
Crude carbolic acid, 100 per cent (dark)	pint	1

This emulsion should be made the same as kerosene emulsion. The carbolic acid is emulsified in the hot water with the soap.

Crude carbolic acid has been used in the various crude-oil sprays for ants, and the tests show that the amount of free oil which usually appears on these emulsions is practically eliminated.

CRUDE-PETROLEUM EMULSION WITH SAL SODA.

This formula has been used on trees which were infested with purple and white scales and sooty mold.

Crude petroleum	gallons	5
Water	do	5
Whale-oil soap	pounds	2½
Sal soda	do	2

Place the oil in a barrel. Dissolve the soap and sal soda in boiling water. Mix the two by pumping back into the barrel for 15 to 20 minutes. Stock emulsions made according to this formula have given satisfactory results. Use 1 part stock solution to 15 parts of water.

LIME SULPHUR.

Lime sulphur is one of the few simple sprays which we have that has insecticidal and fungicidal properties, and for this reason it is becoming more and more popular. The only objectionable feature is the boiling, which takes from 40 to 60 minutes. The formula is as follows:

Fresh lime	pounds	20
Flowers of sulphur	do	15
Water	gallons	60

Place the sulphur in an iron kettle and add 1 or 2 gallons of water, making the whole into a thick paste; heat, and when the mixture reaches the boiling point add the lime. Sufficient water must be added from time to time to slake the lime, after which the mixture is left to boil until it becomes a dark olive green; this generally takes from 40 to 60 minutes. After the mixture has been thoroughly boiled, sufficient water is added to make 15 gallons, then it is strained and the remaining 45 gallons of water are added. This water does not need to be heated, as the boiled portion of the spray contains sufficient heat to keep the mixture warm while it is being put on the trees. It should be applied warm, although good results have been obtained with cold lime-sulphur spray. In making large quantities of this mixture steam should be used for boiling.

Lime-sulphur spray was applied to two rows of orange, grapefruit, and lemon trees in the experimental grove to compare the result with that from other sprays. This spray was made of 20 pounds of unslaked lime, 15 pounds sulphur, and 60 gallons water. All the crawling young scale and full-grown male scale and also a high percentage of females with eggs were found dead. This spraying was done on January 16, 1907, and eight days later no crawling young were found.

The results with lime sulphur are not equal to those obtained with the miscible oils made with kerosene, paraffin, or crude oil, but they are far superior to the results obtained with the kerosene emulsion. The cost of the lime-sulphur wash is about the same as that of miscible oils 1 to 20, but as it is advisable to use the oil 1 to 25, or in some cases 1 to 30, it makes the cost of the latter less than that of lime sulphur.

Lime sulphur is not only a good insecticide, but it also has fungicidal properties. In groves where lime sulphur has been used there is practically no scale and very little rusty fruit. While this spray was used for the purple scale, it also held the rust mite in check.

Great care should be taken in applying a fungicide unless it contains some insecticidal properties. The various scales are preyed upon by beneficial fungi, which are sure to be killed by the fungicides; therefore it is recommended to apply an insecticide before or just after using a fungicide, so that the scale will not get too vigorous a start and injure the fruit; or it is still more practical to apply a spray which is in itself a fungicide and an insecticide. Lime sulphur seems to meet these two qualifications. This spray has at least two advantages over the oil emulsions; it remains on the trees and fruit for three to four months and during this time seems to retain some of its beneficial properties. When it dries it is white, and thus one can readily see what part of the tree has been left unsprayed.

The fungicidal properties of lime sulphur do not remain on the trees as long as Bordeaux mixture. This has been observed in a grove where Bordeaux mixture was used, and the beneficial fungi did not begin to control the scale until after the first year. Lime sulphur was applied in the same grove, and at the end of six months beneficial fungi had established themselves and were checking the work of the scale.

CAUSTIC SODA AND SULPHUR WASH.

The following formula has been used extensively for red spider and rust mite in Florida:[1]

Flowers of sulphur	pounds	20
Caustic soda, 98 per cent	do	10
Water	gallons	20

For spraying use 2 gallons stock emulsion to 50 gallons of water. This strength kills the mite and spider, but not their eggs. Sulphur may be added to kerosene and crue-oil emulsions as a remedy for mite and red spider.

[1] U. S. Dept. Agr., Farmers' Bul. No. 127 (rev. ed.).

FORMULA FOR EMULSION FOR ANTS.

Although the ant is a biting insect, very unsatisfactory results have been obtained by the use of stomach poisons, as ants will only eat the bait for a little while. By the use of contact poisons ants can, however, be combated. The following formula has been used with great success:

Water	quart	1
Soap (Good's caustic potash or whale-oil soap or Fairbank's blue cloud soap)	pound	½
Crude carbolic acid, 100 per cent (dark)	pint	1

Dissolve the soap in water and add the crude carbolic acid, then add sufficient water to make 2 quarts. This should be used as a stock solution, using 1 pint of the stock to 6 gallons of water.

BORDEAUX MIXTURE.

Bordeaux mixture is used in combination with arsenate of lead. In this way two sprays are applied at once—a stomach poison and a fungicide. This is far more economical and fully as good results are obtained as when the two sprays are used separately. The formula for Bordeaux mixture is as follows:

Copper sulphate	pounds	4
Quicklime	do	6
Water	gallons	50

Dissolve the copper sulphate in 25 gallons of water. This is very easily done by putting the copper sulphate in a bag which is suspended by a rope in a barrel; this enables one to determine if all the sulphate is dissolved. Slake the lime in a small amount of water, then add sufficient water to make 25 gallons. The two ingredients, copper sulphate and lime, may be used as a stock solution. For making Bordeaux, use equal parts of the two, pouring them into the spray tank at the same time.

Wooden vessels should be used for the mixing of the above, as Bordeaux mixture corrodes iron.

Stock solutions of Bordeaux mixture may be made by slaking 50 pounds of lime in a barrel and adding sufficient water to make 25 gallons, then for each barrel of spray use 3 gallons of the lime mixture. In the same way dissolve 50 pounds copper sulphate in 25 gallons of water and use for each barrel of Bordeaux 2 gallons of this solution. To obtain the best results each of these solutions should be prepared separately with 25 gallons of water and then combined.

In spraying with Bordeaux mixture a pump with a good agitator is necessary, as the precipitate, which is a chemical union of the lime and copper, has a tendency to settle. All parts of the pump should be made of brass, not iron.

HINTS ON PURCHASE OF INGREDIENTS.

Extreme care should be used in purchasing the ingredients for the soap and for the stock emulsions. There are a number of different grades of the various ingredients on the market, but from experience at this station and in the United States it is best to obtain the ingredients direct from large dealers and according to exact specifications. The following specifications and prices are quoted by New York firms:

Pure menhaden, or fish oil, in barrel lots costs from 30 to 37 cents per gallon.

Caustic potash, 92 per cent, ground, can be purchased at 8 to 9 cents per pound by the hundredweight.

There are a number of grades of carbolic acid on the market which range from 20 to 100 per cent. The lower grades are not suitable for making the soap as they have a tendency to produce thick soaps, which do not emulsify the oils. The high-grade 100 per cent crude carbolic acid, of straw color, can be obtained for 40 to 45 cents per gallon in barrel lots. A 100 per cent crude carbolic acid, dark, has also been obtained, which has given equally good results. This costs a few cents less per gallon than the straw color.

Rosin oil is a vegetable oil obtained from the turpentine distilleries and costs from 23 to 26 cents per gallon in barrel lots.

SUMMARY.

The present condition of the citrus industry in Porto Rico is very promising. No insects are found in the groves that can not be held in check by thorough treatment.

For biting insects, arsenate of lead is the best spray for the conditions that exist on the island. Paris green does not have the adhesive power of the arsenate of lead.

Sprays containing oils are used for scale insects, but they will also keep the rust mite and red spider in check. However, where spraying is being done for the rust mite and red spider alone, it would be better to use sulphur sprays.

The purple scale has been the worst enemy, but since windbreaks have been introduced the beneficial fungi play a very important part in checking it.

The hemispherical scale and the Florida red scale are both held in check by the sprays used for the purple and white scales, and so is the white fly. It is very seldom that these insects need special treatment.

It is considered advisable to pick all the fruit before the new blossom growth starts, so that the sprayers may clean the trees well for

the new crop. If the trees are thoroughly cleaned in this way, there is very little chance for the fruit to become scaly.

A great deal of the cultivated fruit has been disfigured either by fungi, mechanical bruises, or by insects. Special attention is called to the last two causes of disfigured fruit. The insects causing the worst scars on fruit are the ants, small orange-leaf weevil, rust mites, and red spiders. The two last mentioned rust the fruit.

All these insects, however, are held in check by sprays described in this bulletin.

Mechanical injuries are caused by the fruit rubbing or hitting against some foreign object, as the leaves or branches.

EMULSIONS.

Of the various oil emulsions which have been introduced the most promising are the miscible oils and the crude-petroleum and kerosene emulsions, the last two being made with crude carbolic acid, 100 per cent (dark).

At the present time miscible oils are recommended only for trees which have not come into bearing. No test has been made on trees with fruit. It may be possible to use these emulsions on trees with fruit by changing the formula, but when this is done a second and perhaps a third spraying will be necessary, as the highly diluted spray kills only the young.

In purchasing materials for homemade miscible oils great care should be exercised to obtain the exact ingredients called for in this bulletin. Homemade miscible oils will not be practical for small planters, as the ingredients in small lots are more expensive. They may be purchased, however, by an association, or a number of small planters may club together to purchase them.

For trees without fruit it is recommended that the small planters use kerosene or crude-oil emulsions made with 100 per cent crude carbolic acid (either straw colored or dark); use 1 to 5 for kerosene emulsion and 1 to 16 or 18 parts of water for crude oil for the purple and white scales, and repeat spraying in three weeks.

For trees in fruit use kerosene or crude-oil emulsions made with 100 per cent crude carbolic acid (either straw colored or dark); dilute them 1 to 8 or 1 to 25 parts of water, respectively, repeating the spraying every two weeks for four or five times.

Kerosene and crude-oil emulsions are greatly improved by the addition of a small amount of crude carbolic acid. When carbolic acid is used the oil particles are more finely divided and the emulsions are more uniform. This is especially true of crude-oil emulsion.

Emulsions made with sal soda are especially adapted to groves having an abundance of sooty mold. This fungus accompanies the Lecanium scale and the white fly.

Lime sulphur wash is the best combination fungicide and insecticide. As an insecticide it is very valuable in combating the purple scale, red spider, and rust mite, and as a fungicide it is used for scab.

Great care should be exercised in applying fungicides, as they kill all the beneficial fungi which prey upon the various scales. At times fungicides have to be applied, but before using them the scale should be well under control; if not, an insecticide should be used immediately after the fungicide.

TIME OF SPRAYING.

Spraying conditions in Porto Rico are very different from those in the United States. Many insects have no definite season of appearance. This is especially true of the scale insects. The constant appearing of the young makes the work of spraying more difficult. It is only by careful study and constant observation that one learns to recognize the condition of trees and is able to determine at what time spraying is necessary.

Sometimes it is necessary to spray a crop of nearly mature fruit; this complicates matters, as a much weaker solution will have to be used than for trees without fruit.

There is no distinct blossoming season of the orange over the island, and the same may be said of the trees in individual groves. Some years there is a very scattering bloom, some trees being in full bloom, while others have not begun to show the blossom growth. The same trees will bloom one year in February and the next year in May or June. There are generally two periods of blooming, one in January and one in July.

The rainy and dry seasons occur at different times in different parts of the island. The Mayaguez district may be having its dry season while the Rio Piedras and Pueblo Viejo districts are having their wet season.

These varying conditions make it impossible to give hard and fast rules regarding the time of spraying.

When the fruit is the size of a pea almost any spray will injure the crop; thus spraying should be deferred until the fruit has reached the size of a walnut, as the fruits are then less liable to be injured by emulsions. A weak emulsion of kerosene, 1 to 8 or 9, or crude oil, 1 to 25, should be used. As these are weak sprays, at least three to five sprayings will have to be given at intervals of two weeks in order to kill all the insects.

WINDBREAKS.

Windbreaks (Pls. IV and V) are as essential to a grove as a breakwater is to an open harbor. In groves which are thoroughly protected little, if any, spraying is needed for the purple and white scales, as the beneficial fungi, which thrive under moist conditions, hold the scale in check.

The mango gives the best permanent windbreak, and next to it comes the bamboo, which grows somewhat faster, but has no commercial value.

Temporary windbreaks are numerous, and among the best are those afforded by the pigeon pea and the various classes of bananas. Bananas produce a very thick break in one year, and in this they excel the pigeon peas. Where trees are planted very close together the pigeon pea, which is a legume, should be used as a break.

SPRAY PUMPS.

The knapsack pump is the most convenient size for spraying very young trees. The barrel pump is the most popular among the planters of Porto Rico. As the groves are developing and more spraying becomes necessary, it will soon be more practical to use power sprayers.

With these more spray can be applied and at a less expense. At the present time some of the planters can not cover their groves in less than three to four weeks, and where sulphur sprays are being used, with a repetition at intervals of two weeks, it is almost impossible to do thorough work, as the spraying outfits are inadequate.